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A COMPARISON OF SURFACE RUNOFF AND SEDIMENT YIELDS FROM LOW- AND HIGH-SEVERITY SITE PREPARATION BURNS[1]

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ABSTRACT: Slash burning is a common site preparation technique used after timber harvest throughout the Southeastern United States. Little quantitative information exists on the hydrologic response to burn severity. This study compared the effects of low-severity and high-severity burns on runoff and sediment yields during rainfall simulation and during natural rainfall in the Southern Appalachian Mountains. Fire severity was largely determined by moisture conditions of the forest floor prior to ignition. Runoff and sediment yield variability was high between plots within the same treatment area due to differences in forest floor characteristics and infiltration rates. Conditions of high-severity resulted when burning was conducted with relatively dry fuels. Sediment yields were 40-times greater for the high-severity treatment areas than the low-severity treatment areas.

(KEY TERMS: erosion; runoff; sediment yield; site preparation burning; timber harvest.)

INTRODUCTION

Foresters, hydrologists, and soil scientists have long been concerned with fire's effects on soil (Arend, 1941; Wells *et al.,* 1979) – in particular, with erosion, site productivity, and water quality following fires on steep terrain (Van Lear and Kapeluck, 1989). Sediment production after fires, whether the fires are prescribed or wild, can be a serious problem nationwide. Little quantitative information is available on the effects of prescribed fires in timber harvest areas on runoff/infiltration and sedimentation. The USDA-Forest Service, Intermountain Research Station is developing physical process models to estimate on-site runoff and sediment production from timber harvest areas and forest roads (Burroughs *et al.,* 1991) in conjunction with the USDA-Agricultural Research Service Water Erosion Prediction Project (WEPP). The development, verification, and validation of such models depends on plot runoff and sediment data gathered under various management conditions.

Post-harvest burning is the most common site preparation treatment used after timber harvest nationwide. Burning is used alone and in combination with other treatments to dispose of slash, reduce the risk of insects and fire hazards, prepare seedbeds, and suppress plant competition for both natural and artificial regeneration. In the Southern Appalachians and Piedmont regions of the Southeast, site preparation burning is commonly used to convert low-quality hardwood stands to pine-hardwood mixtures (Phillips and Abercrombie, 1987).

Several types of burning are commonly employed: brown-and-burn techniques, which use herbicides to kill vegetation and use the dead vegetation to carry the fire; fell-and-burn techniques, which use recently cut slash that has dried for several weeks to carry the fire; and late summer/fall burns, which use dying residual vegetation to carry the fire. The amount of vegetation, residue, and forest floor consumed and the soil heating caused by the burning determine the extent to which soil properties are altered. The effects of fire on the forest floor can range from removing a small portion of the litter (low severity) to total consumption of the forest floor (high severity) and alteration of the mineral soil structure (Phillips and Abercrombie, 1987; Wells *et al.,* 1979). The depth of the forest floor (litter layer and humus layer), its moisture content, and the amount of woody residue determine forest floor consumption. When the forest floor is shallow or moisture content is low, fires

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consume more of the forest floor and have the potential to alter the mineral soil (Reinhardt *et al.*, 1991).

Water and sediment yields may increase as more of the forest floor is consumed (Wells *et al.*, 1979). Burning reduces the amount of rainfall interception by the forest canopy and reduces evapotranspiration. If organic layers are consumed and mineral soil is exposed, soil infiltration and water storage capacities are reduced. Such impacts may last weeks or decades, depending on the degree of damage, remedial measures taken, and the rate of vegetative recovery (Baker, 1990).

Studies on the effects of burning on erosion in the South are limited and have produced conflicting results (Douglass and Van Lear, 1983). Van Lear and Danielovich (1988) reported an erosion rate of 1.59 t/ha/yr after a low-severity prescribed burn on slopes of 21 to 43 percent in the Southern Appalachian Mountains. However, a prescribed burn in the Piedmont region conducted under similar conditions led to an average erosion rate of 463.8 t/ha/yr (Van Lear and Kapeluck, 1989). Shahlaee *et al.* (1991) reported erosion rates of 0.95 t/ha for an eight-month period after a prescribed burn on a 30 percent slope in the upper Piedmont under natural rainfall. Another study in the upper Piedmont was conducted with simulated rainfall to examine the effects of burning on each layer of the forest floor (Robichaud and Shahlaee, 1991). Low-severity burning increased sediment production 11-fold compared to unburned control plots. Ralston and Hatchell (1971) reported a soil loss of 7.4 t/ha/yr in a North Carolina hardwood stand burned semi-annually. These reported differences are likely due to various methods of assessing erosion and runoff, variation in rainfall intensities, slope, conditions of the ground surface, and small-plot versus watershed-scale studies.

Quantitative information is needed to develop physical-based model parameters to predict effects of various site preparation burns on runoff and sediment production. This research had two objectives: (1) to measure runoff and sediment production between low- and high-severity burns as a function of antecedent soil moisture conditions, and (2) compare the runoff and sediment production from simulated and natural rainfall events.

METHODS AND SITE DESCRIPTION

The study was conducted in the Andrew-Pickens Ranger District of the Sumter National Forest, in northwestern South Carolina beginning the summer of 1991. The region is transitional between the central deciduous forest and the prevailing pine forest of the Southeast. Slopes within the study area (14 ha) ranged from 24 to 39 percent with a southern aspect. The predominant soil type is the Cowee series, a fine-loamy, oxidic, mesic Typic Hapludult formed in residuum from weathered granite, gneiss, and schists.

The 14-ha study site was harvested and regenerated by the fell-and-burn technique. The entire area was clearcut during the winter of 1990-91. Logs were removed by skidder and undesirable stems were left standing. The stand consisted of 60 percent hardwood and 40 percent pine with an average basal area of 20.9 m^2/ha. Major overstory hardwood species included: scarlet (*Quercus coccinea* Muenchh.), northern red (*Q. falcata* Michx.), black (*Q. velutina* Lam.), white (*Q. alba* L.), chestnut (*Q, prinus* L.), and post oaks (*Q. stellata* Wangenh.). Shortleaf pine (*Pinus echinata* Mill.) was the predominant overstory pine species. Understory and midstory hardwoods included red maple (*Acer rubrum* L.), blackgum (*Nyssa syvatica* Marsh.), sourwood (*Oxydendron arboreum* L.), persimmon (*Diospyros virginiana* L.), and black cherry (*Prunus serotina* Ehrh.).

Treatment areas for two burns were randomly selected within the 14-ha study site. Treatments included two fire prescriptions designed to produce conditions of low- and high-severity. The low-severity burn treatment area was 6-ha and the high-severity burn treatment area was 8-ha. Standing residual stems greater than 1.5 m tall were chain-saw felled in May on the low-severity burn treatment area and mid-June on the high-severity burn treatment area.

In this study, the term fire severity follows the definition of Wells, *et al.* (1979) and refers to the condition of the forest floor after burning. Low-severity fires leave a majority of the forest floor intact while high-severity burns consume all or most of the forest floor. In many cases, fire severity is proportional to fire intensity. However, fire severity is more closely related to other variables, such as fuel moisture and residence time (Van lear and Waldrop, 1989). A slow-moving backing fire over dry fuels is an example of a low-intensity fire that would consume much of the forest floor and produce conditions of high severity.

Fifteen semi-permanent plots were established on a systematic grid in each burn treatment area. Randomly selected 15-m transect lines were directed radially from each plot center for woody fuel measurements (Brown, 1974). Eight steel pins were installed flush with the forest floor surface in each plot (total of 240 pins) to estimate forest floor consumption. Immediately prior to ignition, samples of the woody fuels, forest floor, and mineral soil were collected to determine moisture content.

Ignition of the low-severity fire was on June 5, six days after a 4-day rainfall that totaled 37 mm. Ignition of the high-severity fire was on July 15, 12 days after a rainfall of 44 mm. Fuel and weather measurements for both fires are presented in Table 1. Prescriptions for both fires fell within guidelines established by USDA-Forest Service, Southern Region for relative humidity, wind speed, wind direction, and ambient temperature. The Andrew-Pickens Ranger District uses a more conservative set of prescription guidelines to prevent forest floor consumption. Those guidelines are fuel moisture sticks (13 mm ponderosa pine dowels) weighed to estimate the moisture content of 10-hr timelag fuels (woody fuels 6-26 mm in diameter). The Ranger District has not burned unless the moisture content of the sticks was 9 percent or higher. The Regional guideline of 8 percent was used for the high-severity burn to determine if this moisture level would affect erosion rates, thus increasing the number of acceptable burning days in the summer. All other parameters fell within the Southern Region and District guidelines.

TABLE 1. Fuel and Weather Conditions at the Time of Ignition for the Low- and High-Severity Burns.

Measurement	Low Severity	High Severity
Relative Humidity	48%	55%
Wind Speed	5-11 kph	8-11 kph
Wind Direction	SE	SE
Ambient Temperature	18°C	30°C
Fuel Moisture Sticks	11%	8%
Woody Fuel Moisture (6-26 mm in diameter)	17.7%	6.3%
Litter Moisture	65.2%	5.9%
Humus Moisture	98.2%	36.9%
Soil Moisture	35.7%	24.5%

Temperatures during the fire were recorded at ten locations in each burn treatment. Thermocouples were placed at the forest floor-mineral soil interface, and 10 mm into the mineral soil. Temperatures during the burn were recorded at 15-sec intervals by a data logger buried nearby. Postburn fuel measurements were taken several days after burning to allow any smoldering fuels to burn out and to allow ash to settle.

After each burn, four sites were located randomly in each burn treatment area (eight total) for simulated rainfall experiments. Three plots, one large (3 m wide by 7.5 m, 22.5 m^2) and two small (0.5 m wide by 1 m, 0.5 m^2) were established at each site. The large plots were left undisturbed after burning and used to examine runoff and sediment production. The two small plots were used for a paired comparison to learn how well the residual forest floor after burning protected the site from runoff and sediment loss. One of the small plots was left undisturbed after burning. On the other small plot, the residual forest floor was carefully removed with minimal disturbance to the underlying mineral soil. All small and large plots were isolated by 150-mm wide sheet metal placed vertically 50 mm into the ground.

Three 30-min simulated rainfall events were applied to large and small plots at each site with a USDA-Forest Service rainfall simulator. This simulator was modified from the Purdue oscillating nozzle rainfall simulator design developed by Foster *et al.* (1982). The nozzle opening was on the axis of oscillation with a nozzle pressure of 41 Kpa and a fall height of 3 m. A network of 34 nozzles spaced 1.5 m part applied rain uniformly over the three plots. The rainfall simulator produced an average rainfall intensity of 100 mm/hr, which represents a 10-yr event for a 30-min rainfall in the region (Purvis, 1988). Twelve rain gauges located within and around the perimeter of the large plots verified rainfall amounts. Run 1 was conducted with the existing soil moisture condition. Afterwards, the plots were covered with plastic tarps. Run 2 was conducted the following day; Run 3 was conducted about 30 minutes after Run 2. This sequence was used to determine characteristics affecting soil infiltration and runoff under various moisture conditions. Soil moisture conditions prior to each rainfall event were measured with the time-domain reflectometry (TDR) technique (Topp *et al.*, 1982). Four locations in each plot were used for the TDR measurements.

A covered trough at the lower end of each large and small plot conducted runoff (water and sediment) through an outlet tube for timed volume samples, collected manually in 1000 mL bottles. At the end of each run, any sediment in the trough was washed into bottles. All runoff samples were weighed and oven-dried to determine runoff rates and sediment yields.

After simulated rainfall experiments were completed, one large plot from each burn treatment was selected for runoff collection under natural rainfall events. Total runoff and sediment yield were collected in barrels installed below the plot. Each barrel was sampled and cleaned after each rainfall event for one year after burning. Vegetation was allowed to regrow naturally on plots. Although these data were not replicated, they provide some insight to the recovery period required after each fire to minimize runoff and sediment loss.

RESULTS AND DISCUSSION

The major difference between low-severity and high-severity burn prescriptions was the moisture content of the forest floor prior to ignition (Table 1). Prescription guidelines do not exist for these variables since they are difficult to measure in the field. Moisture content of the litter layer (the upper layer of the forest floor containing freshly fallen leaves and twigs that have not decomposed) was 65.2 percent for the low-severity fire but only 5.9 percent for the high-severity fire. For the humus layer (located between mineral soil and the litter layer, consisting of partially or entirely decomposed organic matter and fine, woody roots), moisture content was 98.2 percent for the low-severity burn and 36.9 percent for the high-severity burn. Soil moisture was 35.7 percent for the low-severity burn and 24.5 percent for the high-severity burn. Moisture in the woody fuels (6-26 mm diameter) averaged 18 percent for the high-severity burn and 6 percent for the low-severity burn.

The high-severity prescription produced a fire that was hotter and faster than the low-severity fire (Table 2). Flames in the high-severity burn were approximately twice as long as those in the low-severity burn (6 vs. 3 m), and the rate of spread was 12 times greater (18 vs. 1.5 m/min) in the high-severity burn. Forest floor and soil temperatures confirmed the relative differences in fire severity (Table 2). The low-severity burn had a 10-min average temperature of 118°C at the mineral soil-forest floor interface and 50°C in the mineral soil (10 mm deep) with maximum temperatures of 175°C and 70°C, respectively. The high-severity burn had several temperatures over 450°C at the mineral soil-forest floor interface and a 10-min average temperature of 43°C. The high-severity burn had a maximum temperature of 400°C in the mineral soil and a 10-min average temperature of 281°C.

The two burn prescriptions resulted in widely differing forest floor conditions which were typical of low- and high-severity conditions. The low-severity burn consumed an average of 73 percent of the litter layer and only 30 percent of the humus (Table 2). In contrast, the high-severity burn consumed an average of 96 percent of the litter layer and 76 percent of the humus. Another indicator of the difference in fire severity was the portion of each area on which all litter and humus was consumed. Mineral soil was exposed on only 7 percent of all sampled points on the low-severity area, but on 63 percent of the points sampled in the high-severity area. All woody fuels less than 6 mm in diameter were consumed by the high-severity burn, but 20 percent remained after the low-severity burn.

A limitation of this study was a difference in the depth of the preburn forest floor between the two treatment areas. The forest floor averaged 113 mm deep on the low-severity area, but only 71 mm deep on the high-severity area. Since fuel measurements were taken immediately prior to burning, this difference was not discovered until after the low-severity burn had been completed.

TABLE 2. Selected Fire Behavior Parameters and Fuel Consumption Characteristics for Low- and High-Severity Burns.

Measurement	Low Severity	High Severity
Firing Technique	Strip Headfire	Strip Headfire
Flame Height	1-3 m	2-6 m
Fireline Intensity	215-2945 kw/m	655-13295 kw/m
Max. 10-min Average Temperature		
At Mineral Soil Surface	118°C	436°C
At 10 mm Below Mineral Interface	50°C	281°C
Preburn Litter Depth	37 mm	29 mm
Postburn Litter Depth	10 mm	1 mm
Preburn Humus Depth	76 mm	42 mm
Postburn Humus Depth	53 mm	10 mm
Woody Fuels (0-6 mm in diameter)		
Preburn	0.87 t/ha	0.48 t/ha
Postburn	0.17 t/ha	0 t/ha
Woody Fuels (7-25 mm in diameter)		
Preburn	5.67 t/ha	2.24 t/ha
Postburn	2.76 t/ha	0.82 t/ha

protect the site until revegetation occurs. If land managers can meet their silvicultural objectives with low-severity burns, it will greatly reduce the amount of sediment leaving a site compared to a high-severity burn and will preserve site quality and productivity. Even though vegetative regrowth is rapid in the region, most of the sediment loss from the high-severity burn occurred in the growing season following burning, indicating that a long period is required for the site to heal. The residual forest floor after the low-severity burn provided excellent protection for the mineral soil from raindrop splash, overland flow detachment, and rill development.

Additional research is needed to identify the spatial variability of fire within harvest units because this variability relates to varying runoff and infiltration rates. A probabilistic approach to model the mosaic patterns of fire severity and corresponding runoff and infiltration rates is needed to accurately predict erosion from large hillslopes as opposed to the small plots used here.

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During the year after burning (September 1991 to September 1992), 31 natural rainfall events ranging from 2.6 to 122 mm of rainfall occurred. The total rainfall at the site was 1318 mm, which was lower than the average annual rainfall (1612 mm) at the nearest NOAA weather station 8 km away (National Climatic Data Center, 1992). Major rainfall events (greater than 25 mm) are summarized in Table 5. Runoff/rainfall ratios for natural rainfall events were similar to those of the simulated rainfall events on the low-severity plots, but the runoff/rainfall ratios for the natural events were lower than for the simulated events on the high-severity plots. A high-intensity thunderstorm (5-min maximum intensity 167.6 mm/hr) on July 22 produced 2081 kg/ha of sediment on the high-severity plot. Two other rainfall events (April 20 and June 3) produced over 900 kg/ha of sediment each. In contrast, the low-severity plots yielded a total of only 137 kg/ha of sediment for the entire year. These results were lower than erosion rates observed by Ralston and Hatchell (1971), Shahlaee *et al.* (1991), Van Lear and Danielovich (1988), and Van Lear and Kapeluck (1989) after a low-severity burn. A thicker forest floor layer protects the low-severity plots from erosion.

CONCLUSIONS

Differences in fire prescription can have large effects on runoff and sediment production. A burn conducted under relatively moist conditions (litter moisture 65 percent and humus moisture 98 percent) resulted in a low-severity burn. The average runoff rate was 0.5 mm, infiltration was high and sediment yield was only 13.6 kg/ha during simulated rainfall events similar to a 30-min 10-yr event for that area. The annual sediment yield was 137 kg/ha under natural rainfall events for the year after the burn.

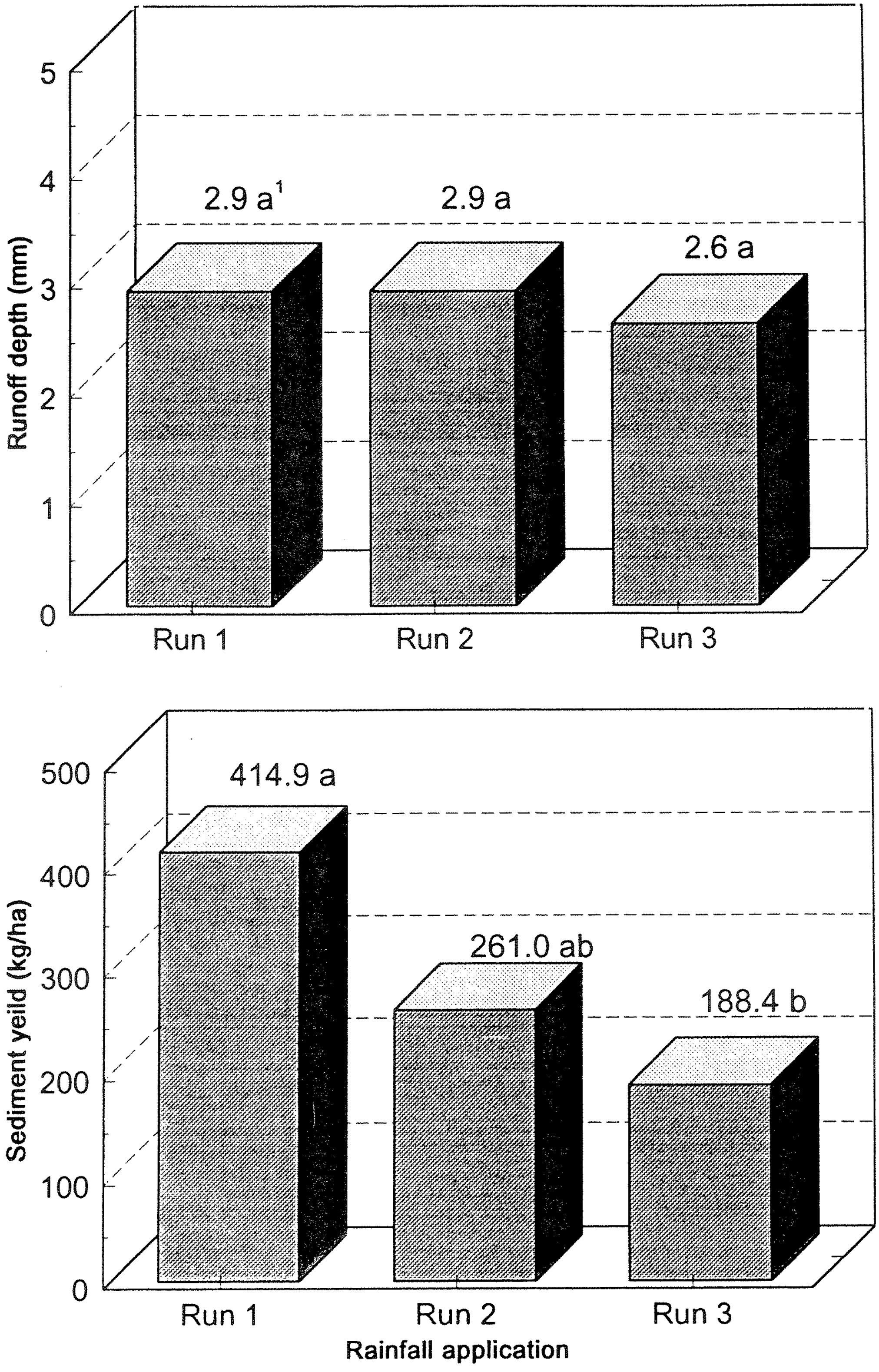
A burn conducted under drier conditions (litter moisture 6 percent and humus moisture 37 percent) increased the average runoff rate to 5.5 mm, decreased infiltration, and increased sediment yield to 562.6 kg/ha during simulated rainfall. Annual sediment yield from natural rainfall was 5748 kg/ha. The major difference between the two treatments was the moisture content of the forest floor prior to ignition, suggesting the need for techniques that will allow the moisture of the forest floor to be measured accurately in the field.

Increases in erosion after the high-severity burn and after removal of the forest floor emphasize the need to maintain a forest floor layer thick enough to

TABLE 5. Summary of 17 Major Rainfall Events from September 1991 to September 1992.

Storm Date	Rainfall Depth (mm)	Rainfall Intensity 5-Minute Peak (mm/hr)	Rainfall Intensity 30-Minute Peak (mm/hr)	Runoff Depth Low Severity (mm)	Runoff Depth High Severity (mm)	Runoff/Rainfall Ratio Low Severity	Runoff/Rainfall Ratio High Severity	Sediment Yields Low Severity (kg/ha)	Sediment Yields High Severity (kg/ha)
27 Sept. 91	28	NA*	NA	0.5	1.6	0.01	0.06	11.7	80.9
30 Nov. 91	67	NA	NA	0.6	2.5	0.01	0.04	4.5	39.0
28 Dec. 91	33	NA	NA	0.2	1.0	0.01	0.03	3.0	9.8
2 Jan 92	28	NA	NA	0.2	0.9	0.01	0.03	1.4	10.0
13 Jan. 92	27	24.4	11.2	0.1	0.9	0.01	0.03	0.8	10.0
22 Jan. 92	41	42.7	18.3	0.6	1.5	0.01	0.04	0.1	5.2
15 Feb. 92	63	21.3	13.2	1.3	2.0	0.02	0.03	1.1	6.2
23 Feb. 92	105	24.4	14.2	1.3	3.6	0.01	0.04	0.7	5.9
5 Mar. 92	77	51.8	16.7	1.0	4.2	0.01	0.04	1.9	99.7
18 Mar. 92	48	21.3	11.2	0.6	1.6	0.01	0.03	4.2	60.1
20 Apr. 92	45	NA	NA	0.9	4.8	0.02	0.11	17.3	927.5
3 Jun. 92	121	76.2	25.4	2.2	14.1	0.01	0.12	4.8	929.8
27 Jun. 92	35	45.7	15.2	0.9	2.5	0.02	0.07	1.2	114.7
22 Jul. 92	71	167.6	98.0	2.1	7.5	0.02	0.11	17.4	2080.6
13 Aug. 92	124	NA	NA	2.3	7.8	0.02	0.06	16.4	458.3
1 Sep. 92	38	70.1	27.9	0.7	5.7	0.02	0.16	2.2	301.2
19 Sep. 92	74	73.1	39.6	0.7	8.2	0.01	0.11	9.6	336.7
Annual Total	**1318**			**16.2**	**70.4**			**136.7**	**5748.3**
Annual Average	**43**	**33.5**	**13.5**	**0.5**	**2.6**	**0.01**	**0.05**	**4.4**	**185.4**

*NA = Not available.



[1]Means within a graph followed by the same letter are not significantly different at the 0.05 level.

Figure 1. Effects of Simulated Rainfall Events on Runoff and Sediment Yields from the Eight Large Plots (22.5 m^2) Combined.

This difference in forest floor thickness was not considered critical, however. Post-burn soil exposure appeared to be controlled more by fuel moisture than by forest floor thickness. At the time of burning, litter and humus moisture was 65 and 98 percent for the low-severity fire and 6 and 37 percent for the high-severity fires, respectively. After 24 hours, the area burned by the low-severity prescription had a blackened appearance indicating that the forest floor was charred, but not consumed, a characteristic of low-severity burns (Phillips and Abercrombie, 1987). In the high-severity area, the forest floor smoldered for approximately three days, and gradually obtained a brown appearance as organic matter was consumed and mineral soil was exposed. The low-severity fire was quickly extinguished due to the high moisture content of the forest floor, but the high-severity fire smoldered until all fuels were consumed.

Slopes varied among study plots, ranging from 24 to 39 percent. Slope differences may affect sediment yields; therefore, sediment yields were adjusted to a uniform slope of 30 percent by the methods of McCool *et al.*, 1987.

Adjusted sediment yields (kg/ha) were 40-times greater from the high-severity large plots than the low-severity large plots (Table 3). Differences in sediment yield among plots were due to variations in runoff rates, which correspond to differences in infiltration rates and forest floor cover and not to differences in erodibility of mineral soil. This variability can be seen in the runoff/rainfall ratios (Table 3). The antecedent soil moisture conditions did not correlate with runoff rates indicating the high variability can be attributed to varying conditions of the forest floor and amount of soil exposure after burning. Burns are rarely uniform over an entire area.

Combining all the large plots and comparing the effects of the three simulated rainfall events, sediment yield decreased by the third rainfall event (Figure 1). One would expect sediment yield to decline with succeeding storms as long as the integrity of the remaining forest floor is left intact.

The residual forest floor in the low-severity burn area prevented sediment loss much better than that in the high-severity burn area (Table 4). Sediment yield was 37 times greater from the small low-severity plots that had the forest floor removed than sediment yield from the small low-severity plots that did not have the forest floor removed. On high-severity plots, however, sediment yield was only 2.5 times greater on the small plots with the forest floor removed. The smaller differences between the high-severity plots emphasize that these plots had little protection from the thin residual forest floor layer that remained.

TABLE 3. Summary of Runoff and Adjusted Sediment Yield for the Eight Large Plots (22.5 m^2). Means of three rainfall simulation events.

Plot	Soil Moisture* (percent)	Runoff Depth (mm)	Runoff/ Rainfall Ratio	Sediment Yields (kg/ha)
		Low Severity		
1	17.7	0.3	0.01	12.2
2	17.1	0.5	0.01	21.6
3	14.8	0.5	0.01	9.2
4	9.4	0.7	0.02	11.6
Average		**0.5**		**13.6**
		High Severity		
1	17.6	11.5	0.28	1386.7
2	18.7	1.1	0.03	89.4
3	18.1	0.4	0.01	10.7
4	18.5	7.3	0.14	763.7
Average		**5.1**		**562.6**

*Gravimetric antecedent soil moisture content in the top 3 cm prior to the first application of the sequence of simulated rainfall events.

TABLE 4. Summary of Runoff and Adjusted Sediment Yields for the 14 Small Plots (0.5 m^2). Existing surface conditions after the fire were compared to removal of the entire forest floor. Means of three rainfall simulation events.

Plot		Runoff Depth (mm)	Runoff/ Rainfall Ratio	Sediment Yields (kg/ha)
		Low Severity		
1	No Plots			
2	Existing	1.1	0.02	97.6
	Bare Soil	17.0	0.30	5417.2
3	Existing	8.3	0.14	122.8
	Bare Soil	29.2	0.50	4984.5
4	Existing	4.6	0.11	119.9
	Bare Soil	11.4	0.28	2267.1
		High Severity		
1	Existing	14.4	0.35	1560.6
	Bare Soil	16.0	0.40	3158.5
2	Existing	29.6	0.84	2186.9
	Bare Soil	18.7	0.53	2999.3
3	Existing	7.7	0.18	189.9
	Bare Soil	18.8	0.44	3133.9
4	Existing	17.6	0.35	1104.7
	Bare Soil	22.9	0.45	3861.6